Application No.: 09/960,445
Docket No.: [illegible]302
Title: Method of Kick Detection and Cuttings Bed Buildup Detection using a Drilling Tool
Inventors: Gzara et al.

FIG. 1

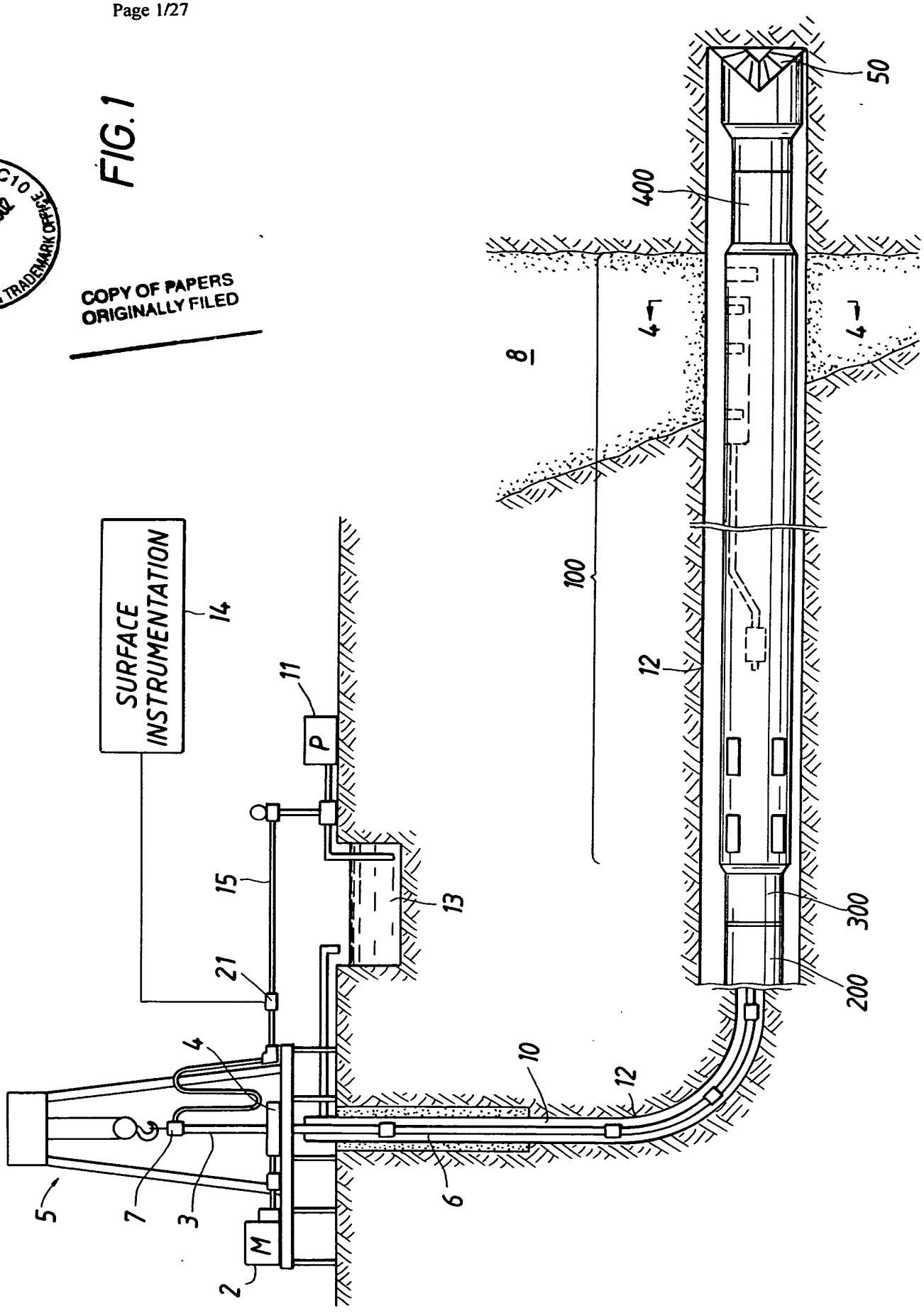


FIG.2

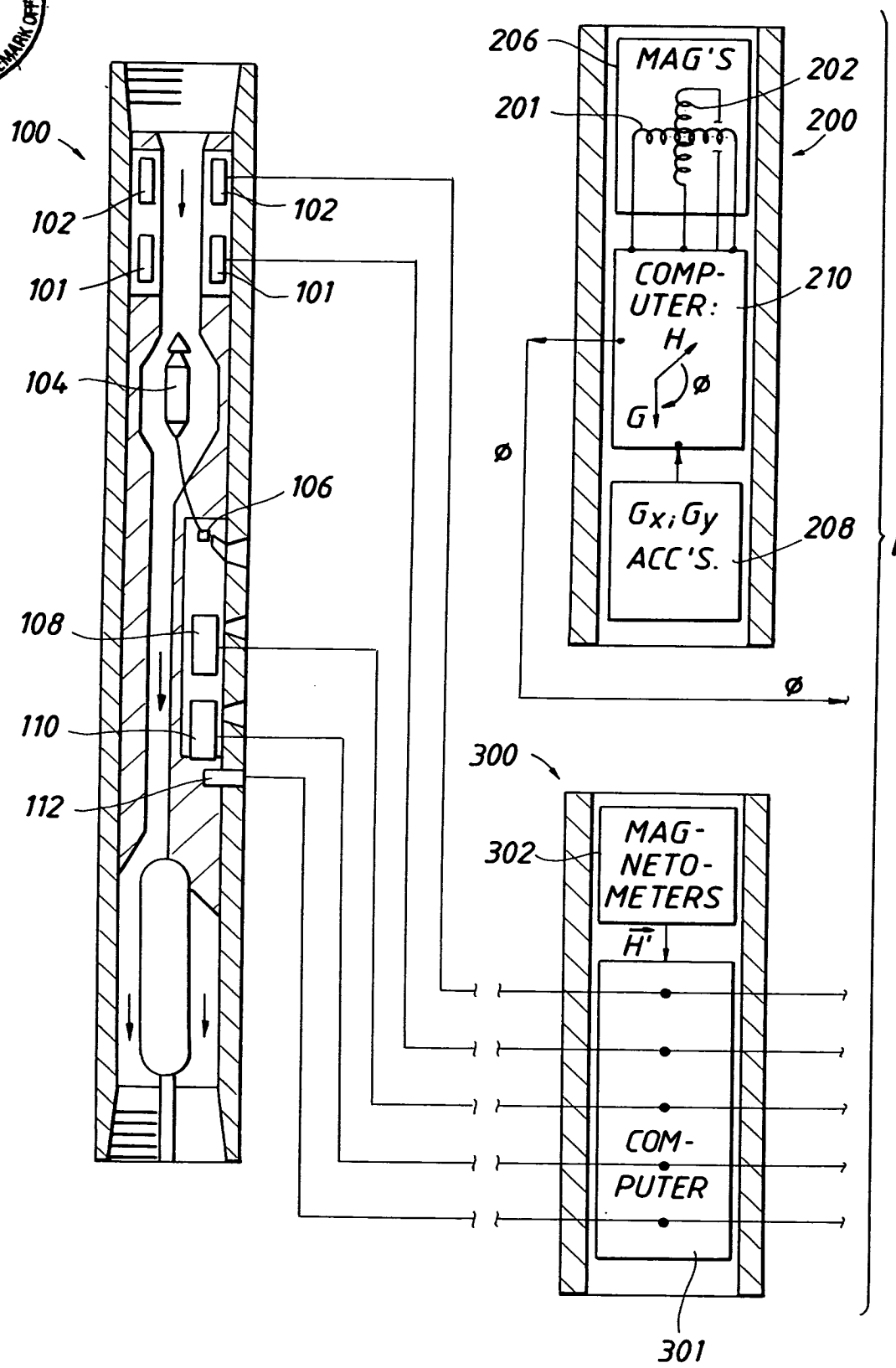


FIG.3A

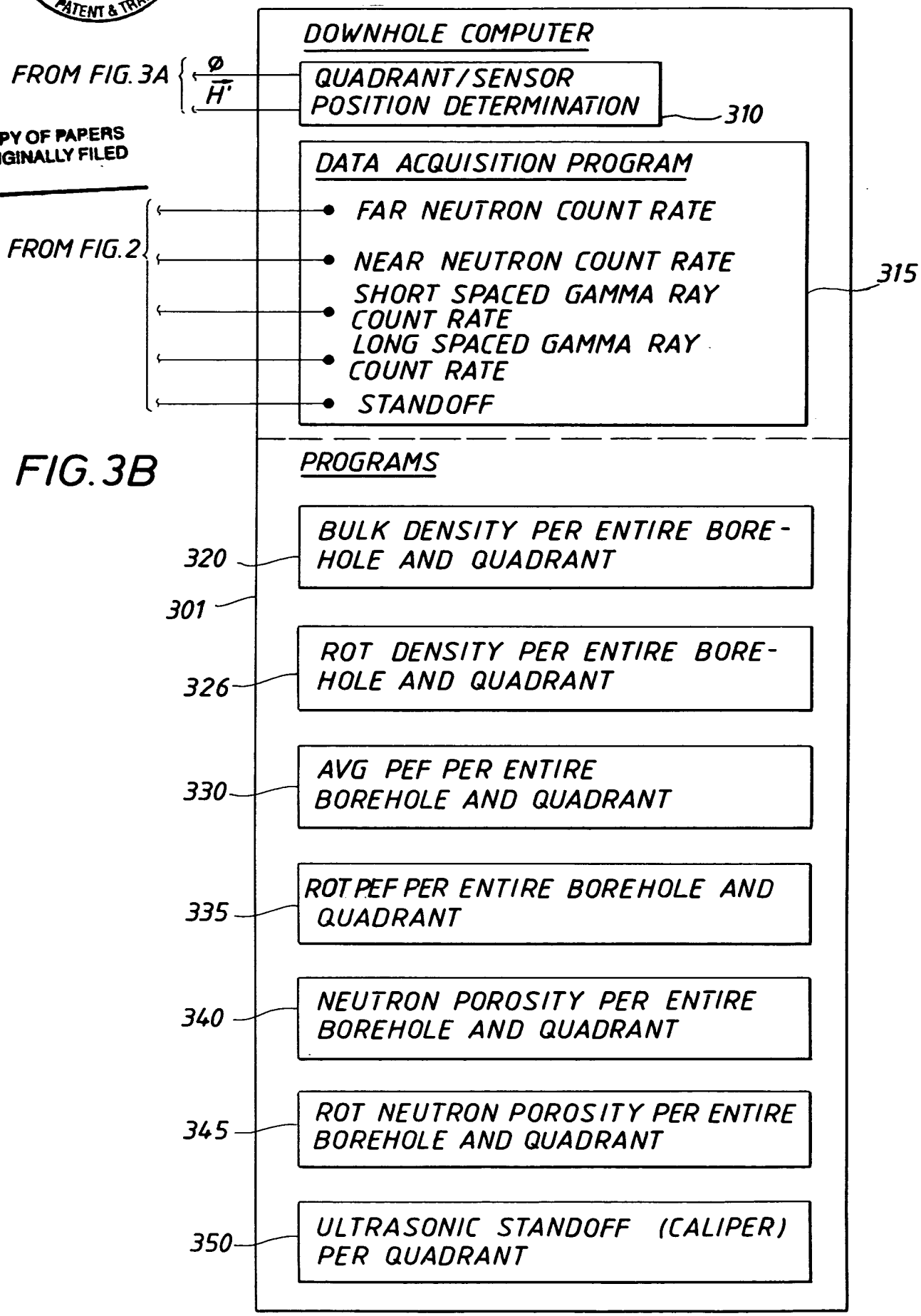
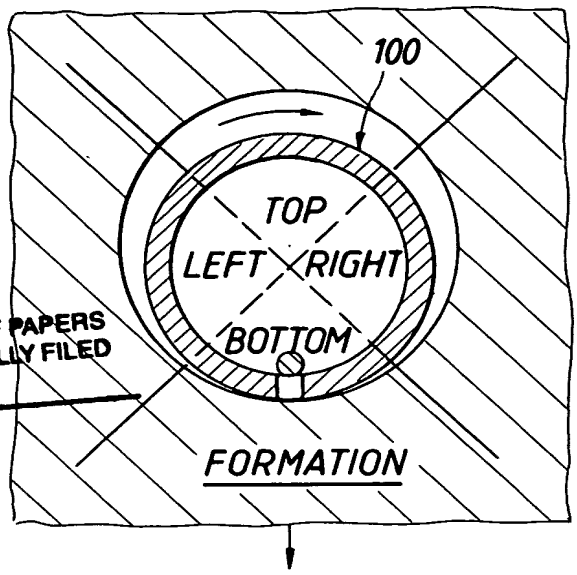


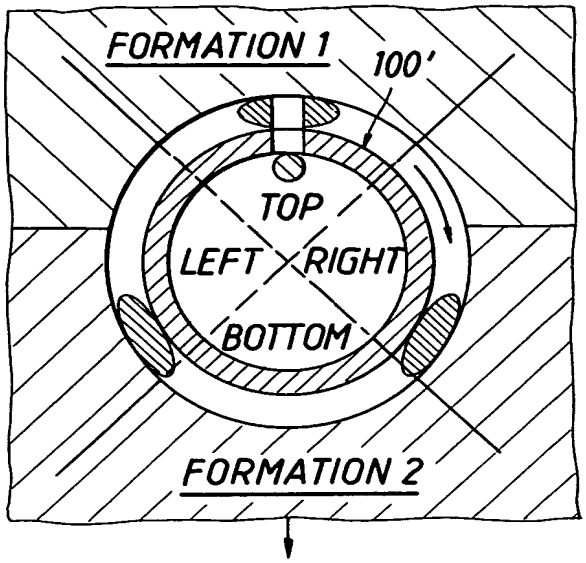
FIG. 3B

Application Serial No.: 09/960,445
Docket No.: 19.0302
Title: Method of Kick Detection and Cuttings Bed Buildup Detection using a Drilling Tool
Inventors: Gzara et al.

FIG. 4A

FIG. 4B





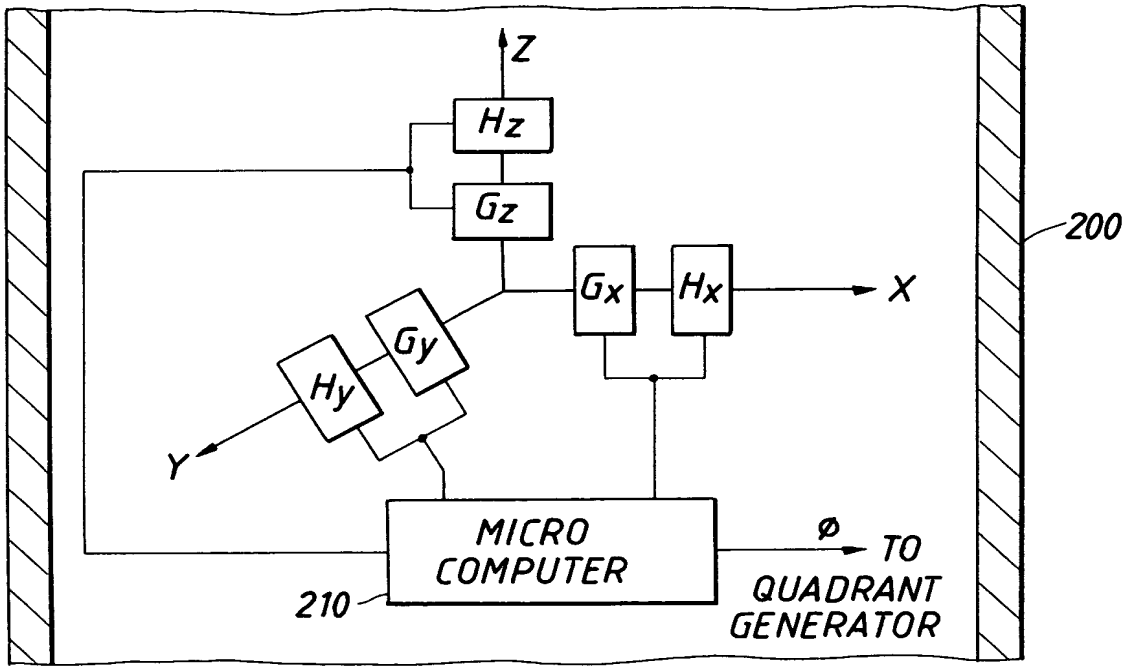


FIG. 5A

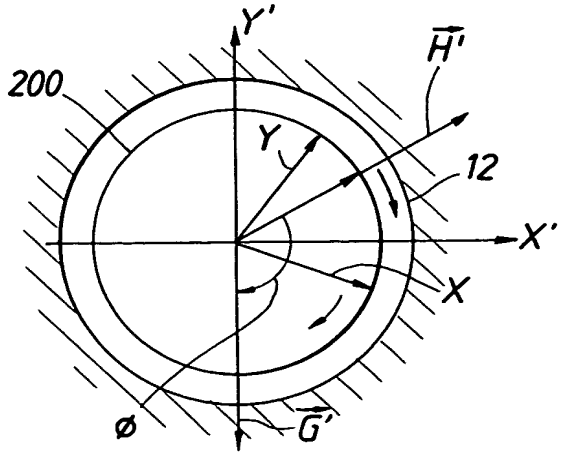
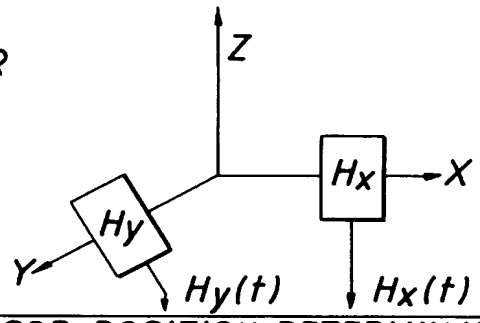


FIG. 5B

FIG. 6A

300

MAGNETOMETER SECTION



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QUADRANT/SENSOR POSITION DETERMINATION COMPUTER PROGRAM

DETERMINE DOWN DIRECTION

- DETERMINE $\vec{H}'(t)$ VECTOR FROM $Hx(t)$, $Hy(t)$, $\angle\theta(t)$
- DETERMINE DOWN DIRECTION ANGLE

$$\theta = \cos^{-1} \frac{Hx(t)}{(Hx^2 + Hy^2)^{1/2}}$$

ø → $\angle\vec{H}'(t) = \theta(t)$ AS MEASURED FROM TOOL X-AXIS
$\angle\vec{D}(t) = \theta(t) - ø$ AS MEASURED FROM TOOL X-AXIS

- DETERMINE BOTTOM QUADRANT

310

$Q_{BOT}(t) = \angle\vec{D}(t) - 45°$ TO $\angle\vec{D}(t) + 45°$
$Q_{LEFT}(t) = \angle\vec{D}(t) + 45°$ TO $\angle\vec{D}(t) + 135°$
$Q_{TOP}(t) = \angle\vec{D}(t) + 135°$ TO $\angle\vec{D}(t) + 225°$
$Q_{RIGHT}(t) = \angle\vec{D}(t) + 225°$ TO $\angle\vec{D}(t) - 45°$

- DETERMINE QUADRANT OF SENSOR

$\angle\vec{S}(t)$ IS MEASURED FROM X-AXIS AND $\vec{H}'(t)$ VECTOR
$\angle\vec{S}$ IS $\propto$ DEGREES FROM X-AXIS
$\angle\vec{H}'(t)$ IS $\theta(t)$ DEGREES FROM X-AXIS
$\angle\vec{S}(t) = \propto$ AS MEASURED FROM X-AXIS IS

IN Q_{BOT} WHEN $\angle\vec{S}(t) = \propto$ IS BETWEEN $\theta(t) - ø - 45°$ AND $\theta(t) - ø + 45°$, ETC.

FIG.6B

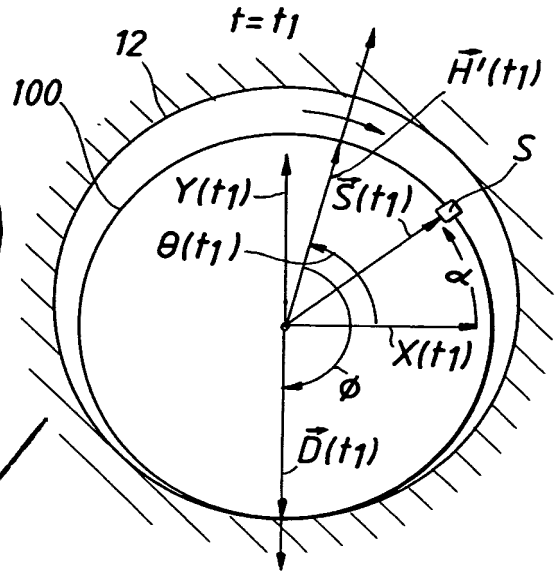
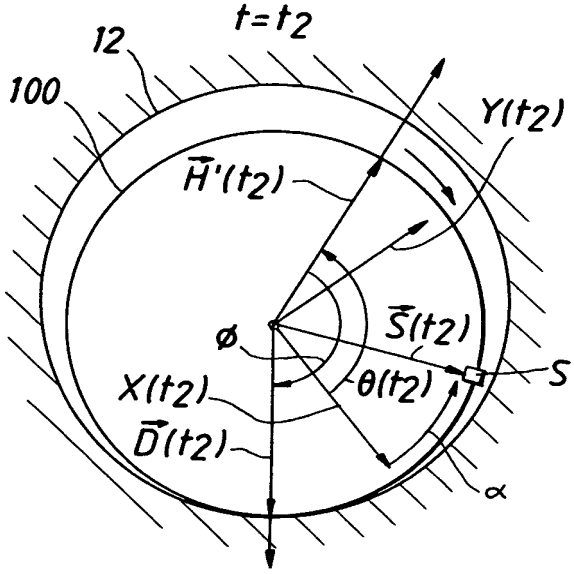


FIG.6C



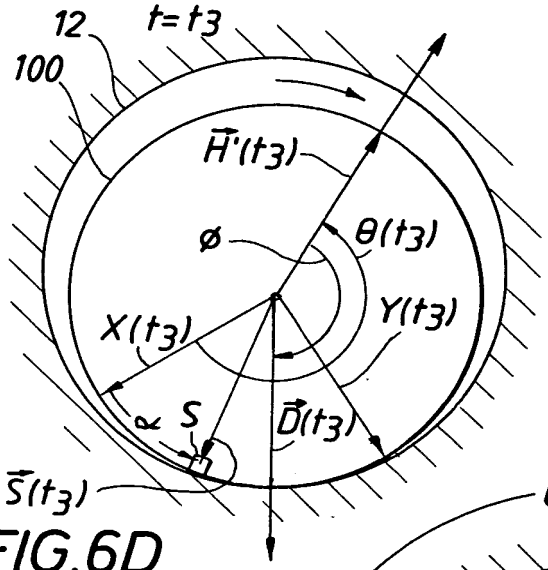


FIG.6D

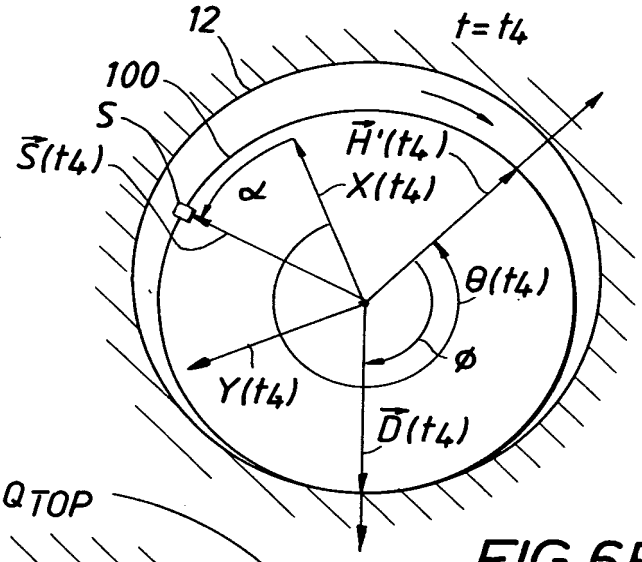


FIG.6E

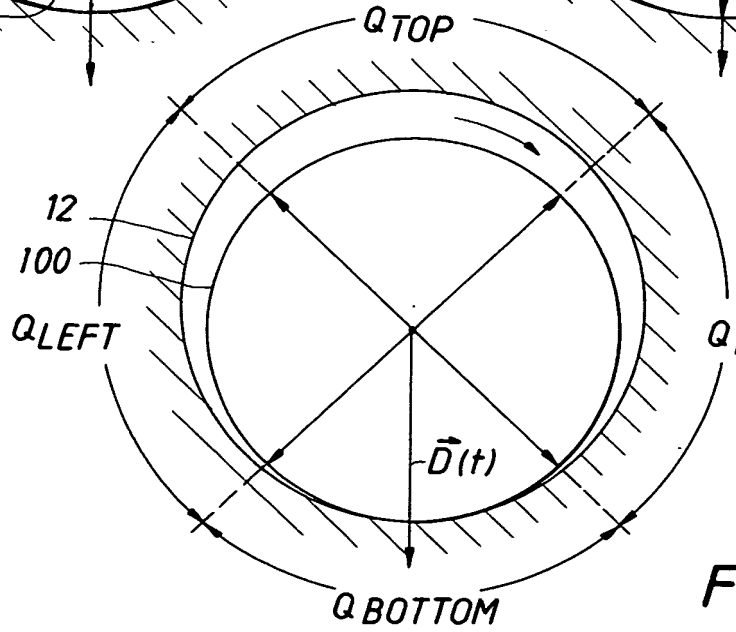


FIG.6F

FIG. 7A

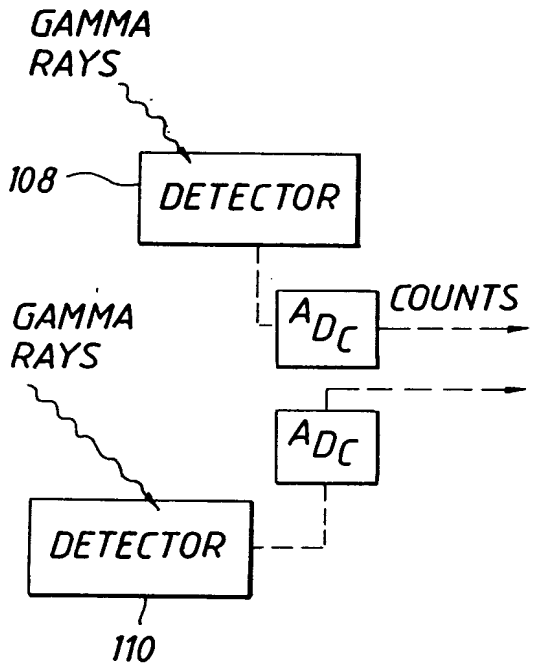


FIG. 7B

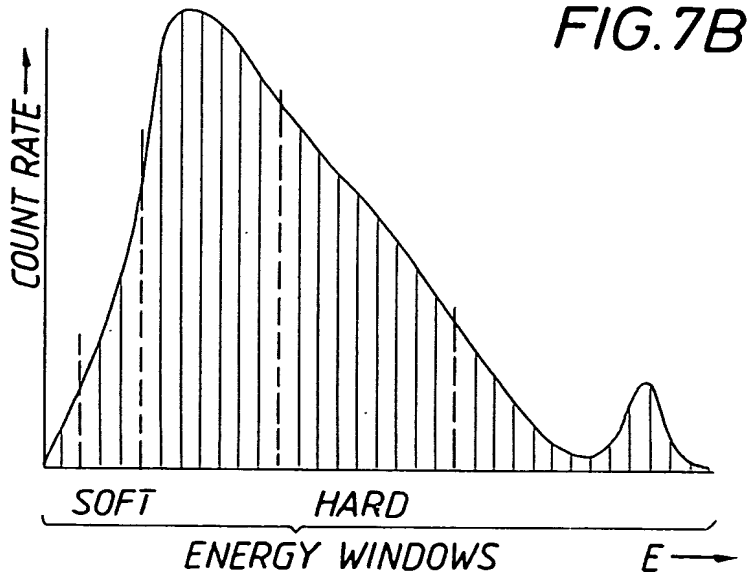


FIG. 8

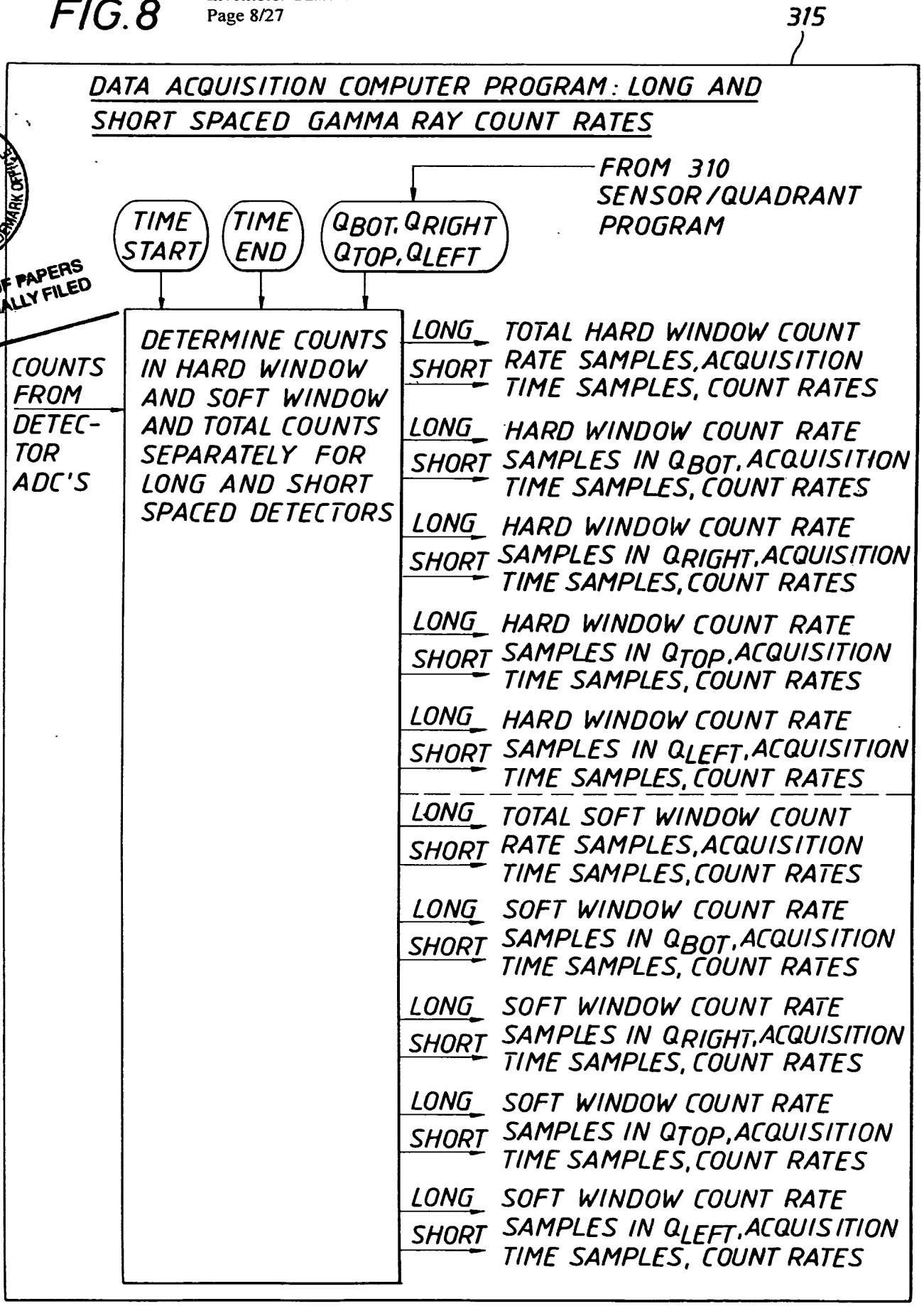


FIG.9

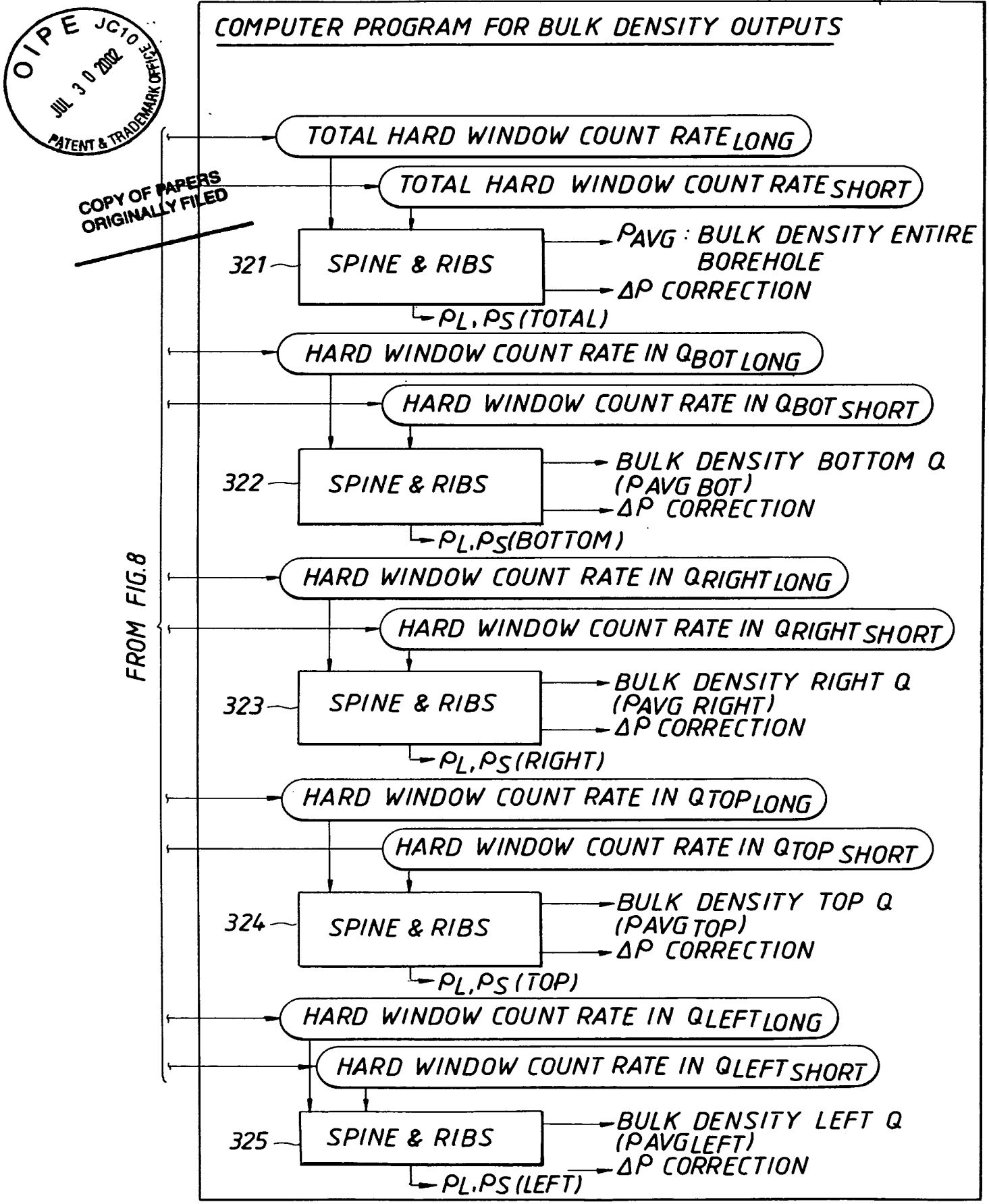
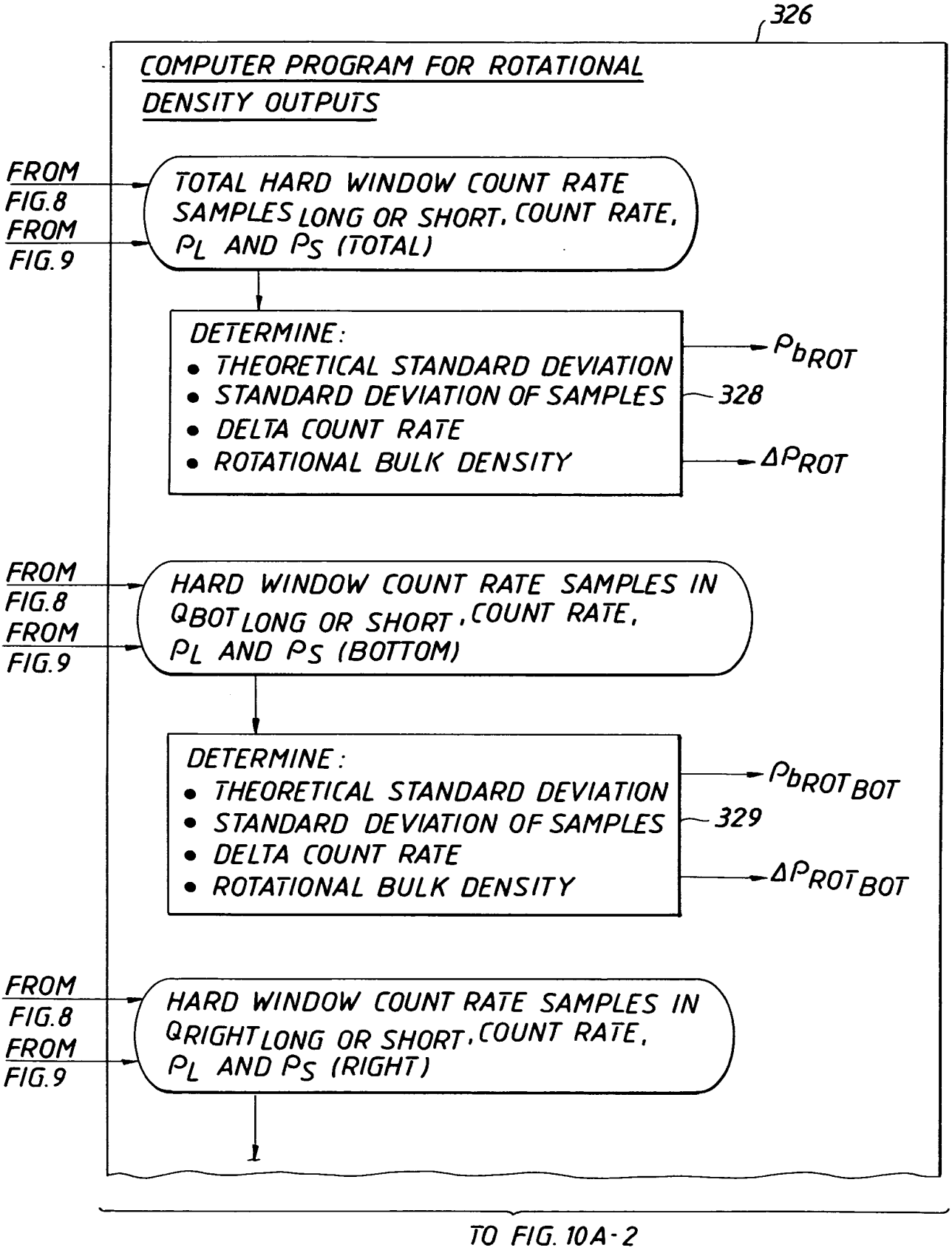
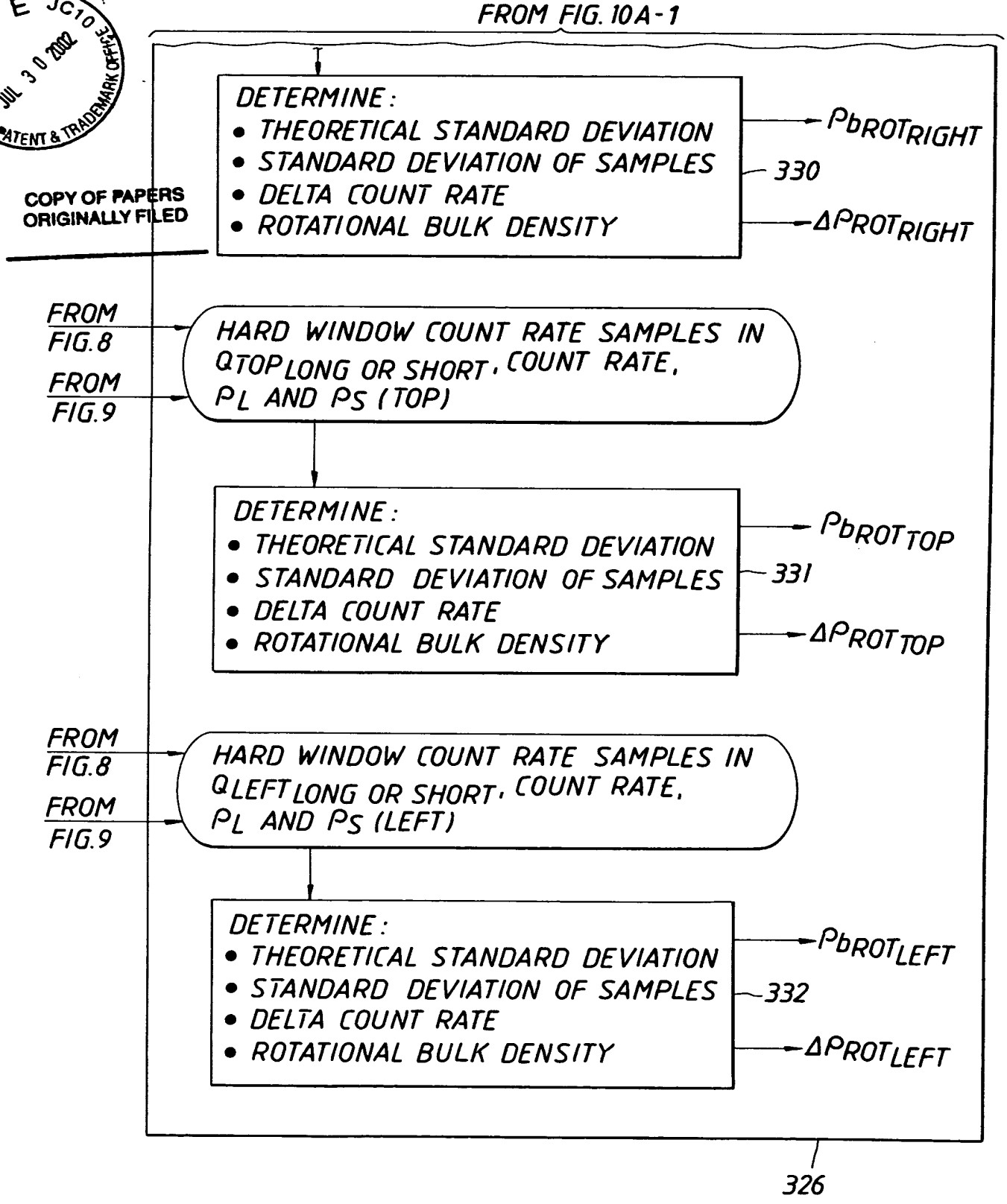


FIG. 10A-1



TO FIG. 10A-2

FIG. 10A-2



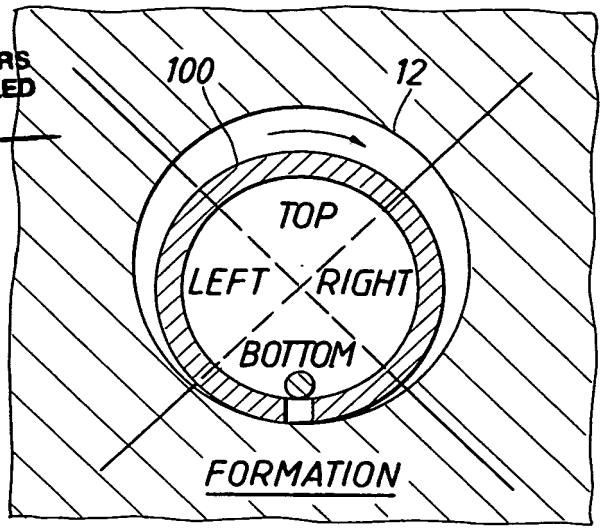


FIG.10B

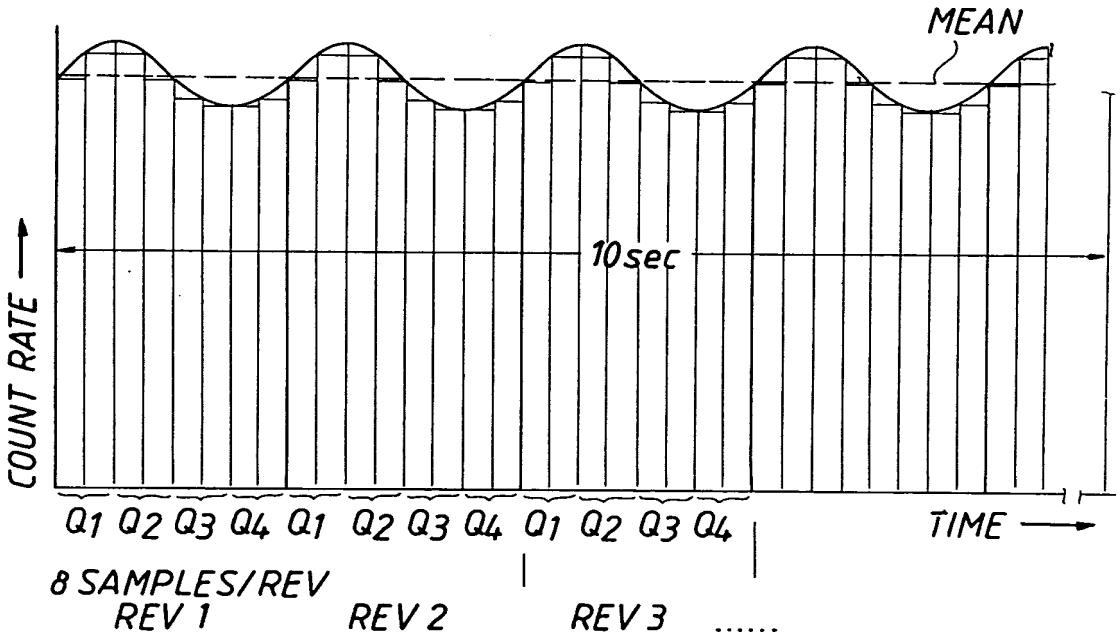
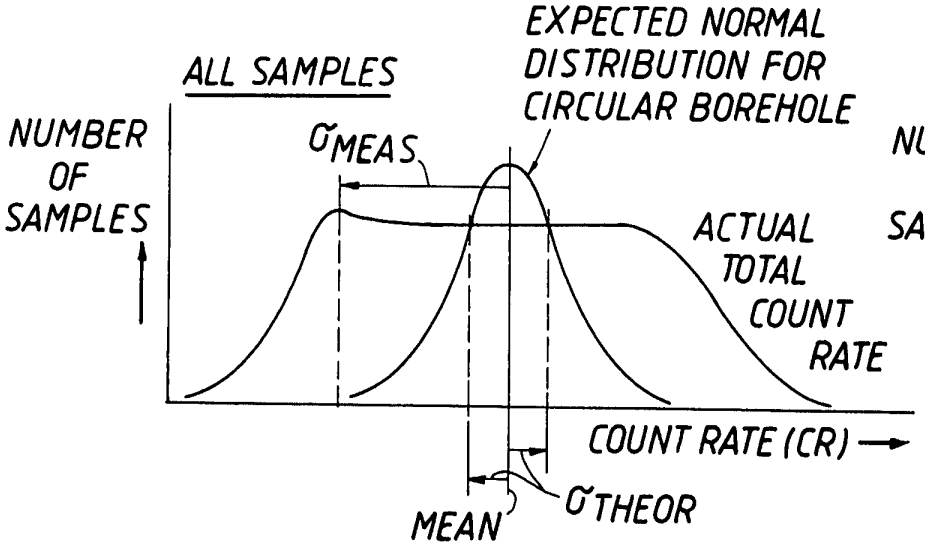


FIG.10C



$$\Delta CR = A\sqrt{\sigma^2 MEAS - \sigma^2 THEOR}$$

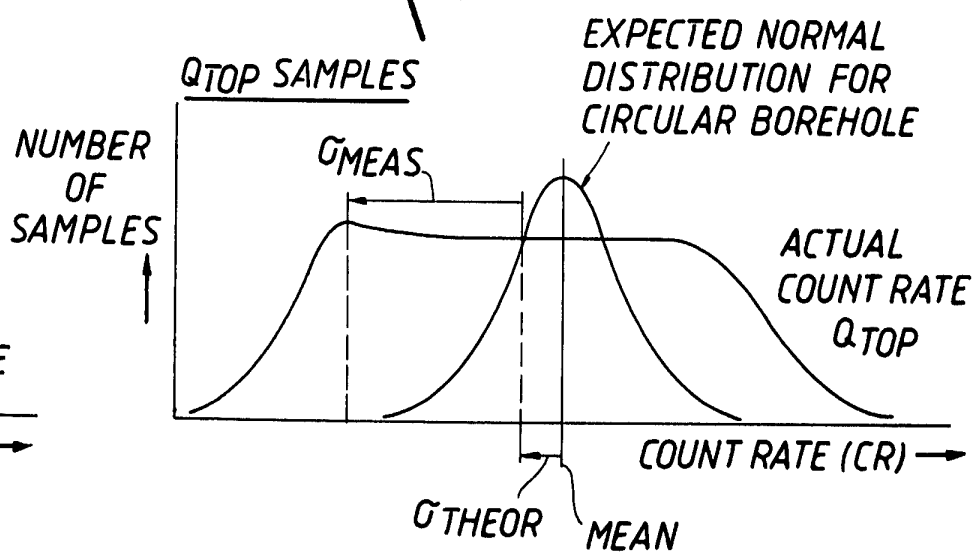
$$\Delta \rho_{ROT} = (ds)\left[\ln\left(\frac{CR+\Delta CR}{CR-\Delta CR}\right)\right]$$

$$\rho_{bROT} = D\rho_L + E\rho_S + F\Delta\rho_{ROT}$$

ρ_L = LONG SPACING DENSITY

ρ_S = SHORT SPACING DENSITY

FIG. 10D-1



$$\Delta CR_{TOP} = A\sqrt{\sigma^2 MEAS_{TOP} - \sigma^2 THEOR_{TOP}}$$

$$\Delta \rho_{ROT\,TOP} = (ds)\left[\ln\left(\frac{CR_{TOP}+\Delta CR_{TOP}}{CR_{TOP}-\Delta CR_{TOP}}\right)\right]$$

$$\rho_{bROT\,TOP} = D\rho_{L\,TOP} + E\rho_{S\,TOP} + F\Delta\rho_{ROT\,TOP}$$

$\rho_{L\,TOP}$ = LONG SPACING DENSITY$_{TOP}$

$\rho_{S\,TOP}$ = SHORT SPACING DENSITY$_{TOP}$

FIG. 10D-2

FIG. 11A

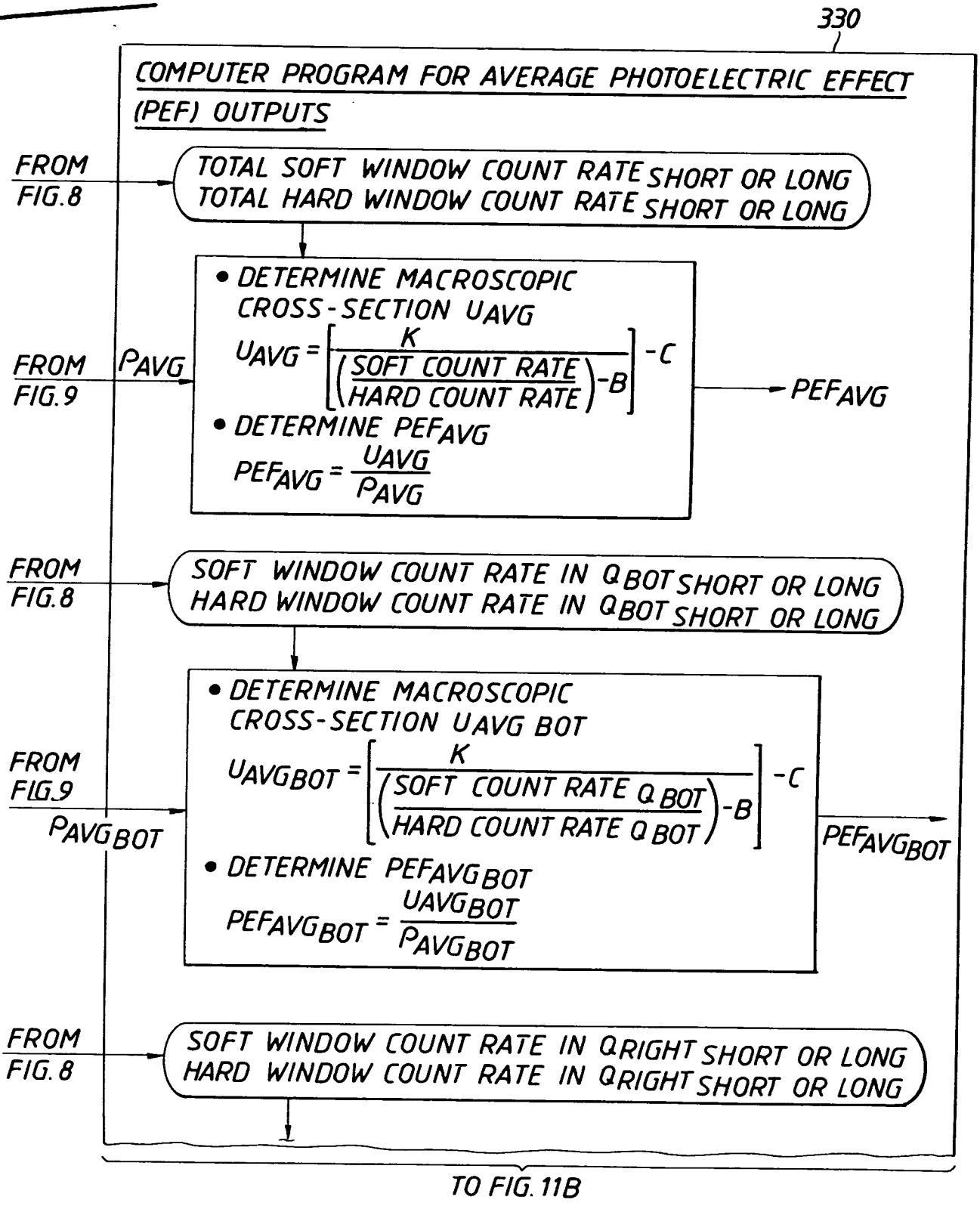


FIG. 11B

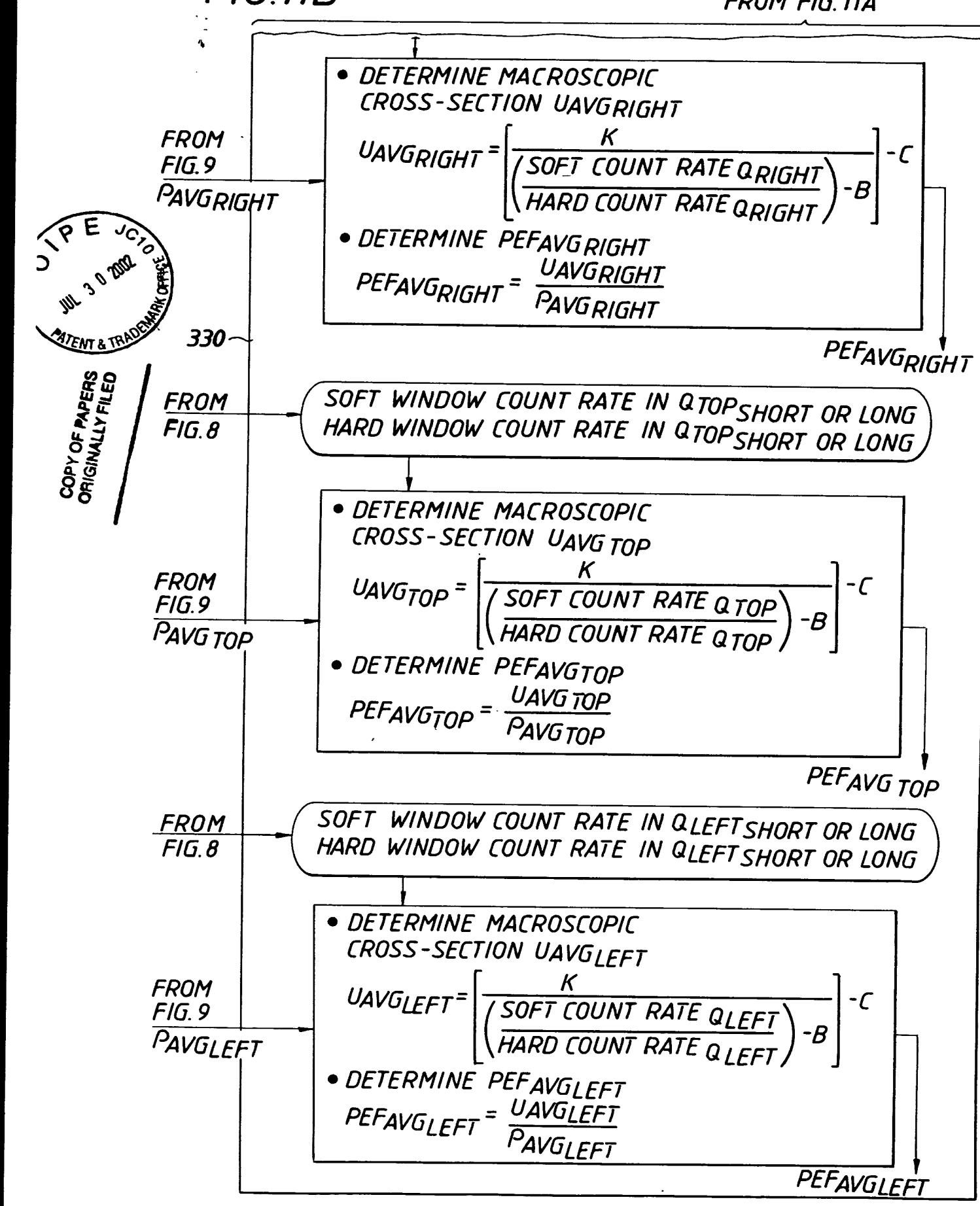


FIG. 12A

335

COMPUTER PROGRAM FOR ROTATIONAL PHOTOELECTRIC EFFECT (PEF) OUTPUTS

FROM FIG. 8

TOTAL SOFT WINDOW COUNT RATE SAMPLES LONG OR SHORT
TOTAL HARD WINDOW COUNT RATE SAMPLES LONG OR SHORT
COUNT RATES

DETERMINE :

- THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
- STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
- DELTA COUNT RATES (SOFT AND HARD)
- MACROSCOPIC CROSS-SECTION U_{ROT}

$$U_{ROT} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE} - \Delta CR_{SOFT}}{\text{HARD COUNT RATE} - \Delta CR_{HARD}} \right) - B} \right] - C$$

- $PEF_{ROT} = \frac{U_{ROT}}{\rho_{b_{ROT}}}$

FROM FIG. 10A-1
$\rho_{b_{ROT}}$

PEF_{ROT}

FROM FIG. 8

SOFT WINDOW COUNT RATE SAMPLES IN Q_{BOT} LONG OR SHORT
HARD WINDOW COUNT RATE SAMPLES IN Q_{BOT} LONG OR SHORT
COUNT RATES

TO FIG. 12B

FIG.12B

FROM FIG.12A

FROM FIG.10A-1

$PbROT_{BOT}$

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DETERMINE:
- THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
- STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
- DELTA COUNT RATES (SOFT AND HARD)
- MACROSCOPIC CROSS-SECTION $UROT_{BOT}$

$$UROT_{BOT} = \left[\frac{K}{\left(\frac{SOFT\ COUNT\ RATE - \Delta CR_{SOFT}}{HARD\ COUNT\ RATE - \Delta CR_{HARD}}\right)^{-B}}\right] - C$$

- $PEFROT_{BOT} = \frac{UROT_{BOT}}{PbROT_{BOT}}$

$PEFROT_{BOT}$

FROM FIG.8

SOFT WINDOW COUNT RATE SAMPLES IN $QRIGHT_{LONG\ OR\ SHORT}$
HARD WINDOW COUNT RATE SAMPLES IN $QRIGHT_{LONG\ OR\ SHORT}$
COUNT RATES

FROM FIG.10A-2

$PbROT_{RIGHT}$

DETERMINE:
- THEORETICAL STANDARD DEVIATIONS (SOFT AND HARD)
- STANDARD DEVIATIONS OF SAMPLES (SOFT AND HARD)
- DELTA COUNT RATES (SOFT AND HARD)
- MACROSCOPIC CROSS-SECTION $UROT_{RIGHT}$

$$UROT_{RIGHT} = \left[\frac{K}{\left(\frac{SOFT\ COUNT\ RATE - \Delta CR_{SOFT}}{HARD\ COUNT\ RATE - \Delta CR_{HARD}}\right)^{-B}}\right] - C$$

- $PEFROT_{RIGHT} = \frac{UROT_{RIGHT}}{PbROT_{RIGHT}}$

$PEFROT_{RIGHT}$

FROM FIG.8

SOFT WINDOW COUNT RATE SAMPLES IN $QTOP_{LONG\ OR\ SHORT}$
HARD WINDOW COUNT RATE SAMPLES IN $QTOP_{LONG\ OR\ SHORT}$
COUNT RATES

TO FIG.12C

FIG. 12C

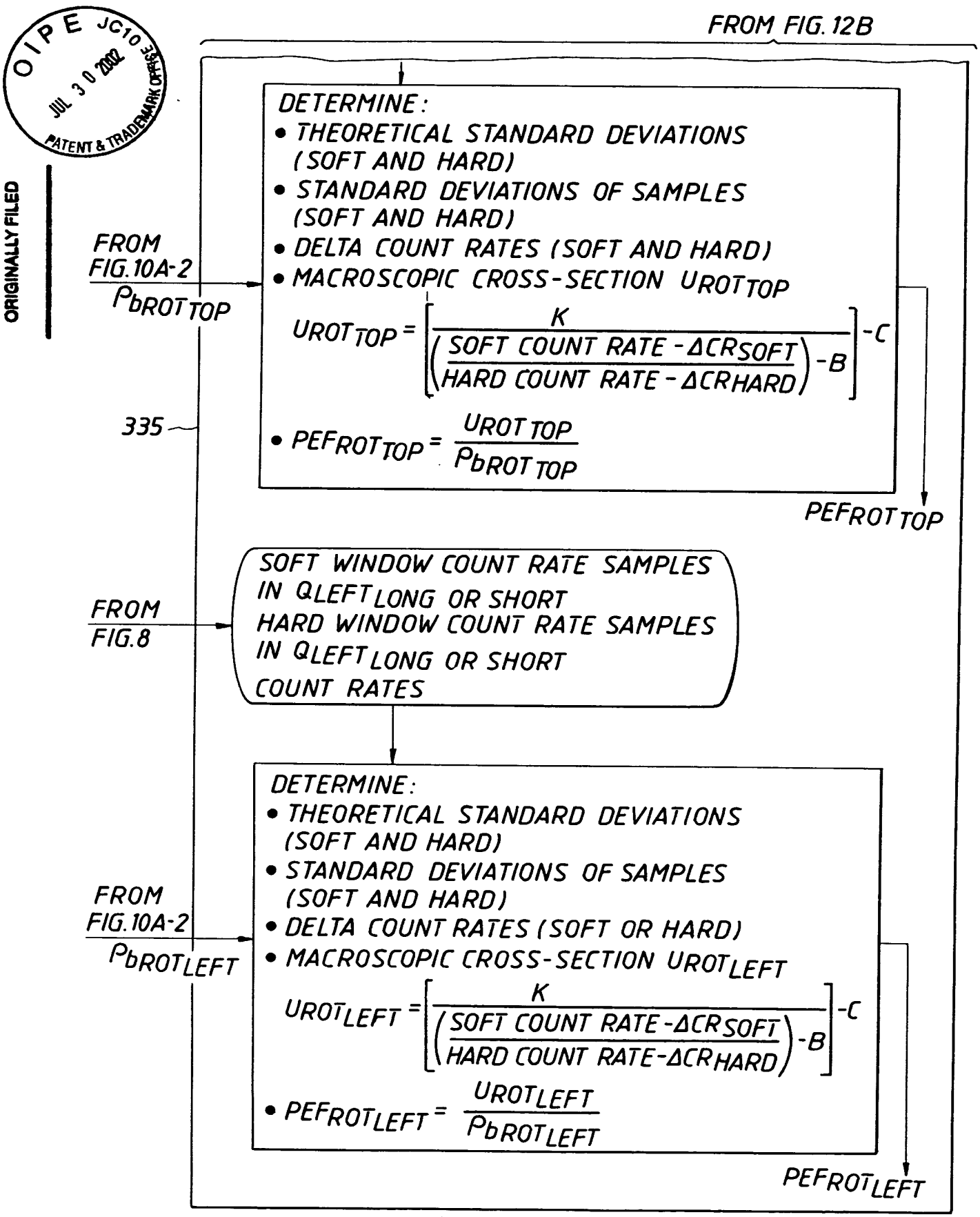

FIG. 12D

335

COMPUTER PROGRAM FOR ROTATIONAL PHOTOELECTRIC EFFECT (PEF) OUTPUTS

FROM FIG. 8

TOTAL SOFT WINDOW COUNT RATE SAMPLES LNG. OR SHT.
TOTAL HARD WINDOW COUNT RATE SAMPLES LNG. OR SHT.
ACQUISITION TIME SAMPLES

- DETERMINE MACROSCOPIC CROSS-SECTION U's AS A FUNCTION OF ACQUISITION TIME

$$Ut = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}}\right) - B}\right] - C$$

- DETERMINE STANDARD DEVIATION FROM Ut's
- DETERMINE PEF_{ROT} FROM DISTRIBUTION OF Ut's

→ PEF_{ROT}

FROM FIG. 8

SOFT WINDOW COUNT RATE SAMPLES IN Q_{BOT} LNG. OR SHT.
HARD WINDOW COUNT RATE SAMPLES IN Q_{BOT} LNG. OR SHT.
ACQUISITION TIME SAMPLES

- DETERMINE MACROSCOPIC CROSS-SECTION U_{BOT}'s AS A FUNCTION OF ACQUISITION TIME

$$Ut_{BOT} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}}\right) - B}\right] - C$$

- DETERMINE STANDARD DEVIATION FROM Ut_{BOT}'s
- DETERMINE $PEFROT_{BOT}$ FROM DISTRIBUTION OF Ut_{BOT}'s

$PEF_{ROT\,BOT}$

TO FIG. 12E

FIG. 12E

FROM FIG. 12D

FROM FIG. 8

SOFT WINDOW COUNT RATE SAMPLES IN $Q_{RIGHT\ LNG.\ OR\ SHT.}$
HARD WINDOW COUNT RATE SAMPLES IN $Q_{RIGHT\ LNG.\ OR\ SHT.}$
ACQUISITION TIME SAMPLES

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- DETERMINE MACROSCOPIC CROSS-SECTION U_{RIGHT}'s AS A FUNCTION OF ACQUISITION TIME

$$U_{tRIGHT} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}}\right) - B}\right] - C$$

- DETERMINE STANDARD DEVIATION FROM U_{tRIGHT}'s
- DETERMINE $PEFROT_{RIGHT}$ FROM DISTRIBUTION OF U_{tRIGHT}'s

→ $PEFROT_{RIGHT}$

FROM FIG. 8

SOFT WINDOW COUNT RATE SAMPLES IN $Q_{TOP\ LNG.\ OR\ SHT.}$
HARD WINDOW COUNT RATE SAMPLES IN $Q_{TOP\ LNG.\ OR\ SHT.}$
ACQUISITION TIME SAMPLES

- DETERMINE MACROSCOPIC CROSS-SECTION U_{TOP}'s AS A FUNCTION OF ACQUISITION TIME

$$U_{tTOP} = \left[\frac{K}{\left(\frac{\text{SOFT COUNT RATE}}{\text{HARD COUNT RATE}}\right) - B}\right] - C$$

- DETERMINE STANDARD DEVIATION FROM U_{tTOP}'s
- DETERMINE $PEFROT_{TOP}$ FROM DISTRIBUTION OF U_{tTOP}'s

→ $PEFROT_{TOP}$

TO FIG. 12F

FIG. 12F

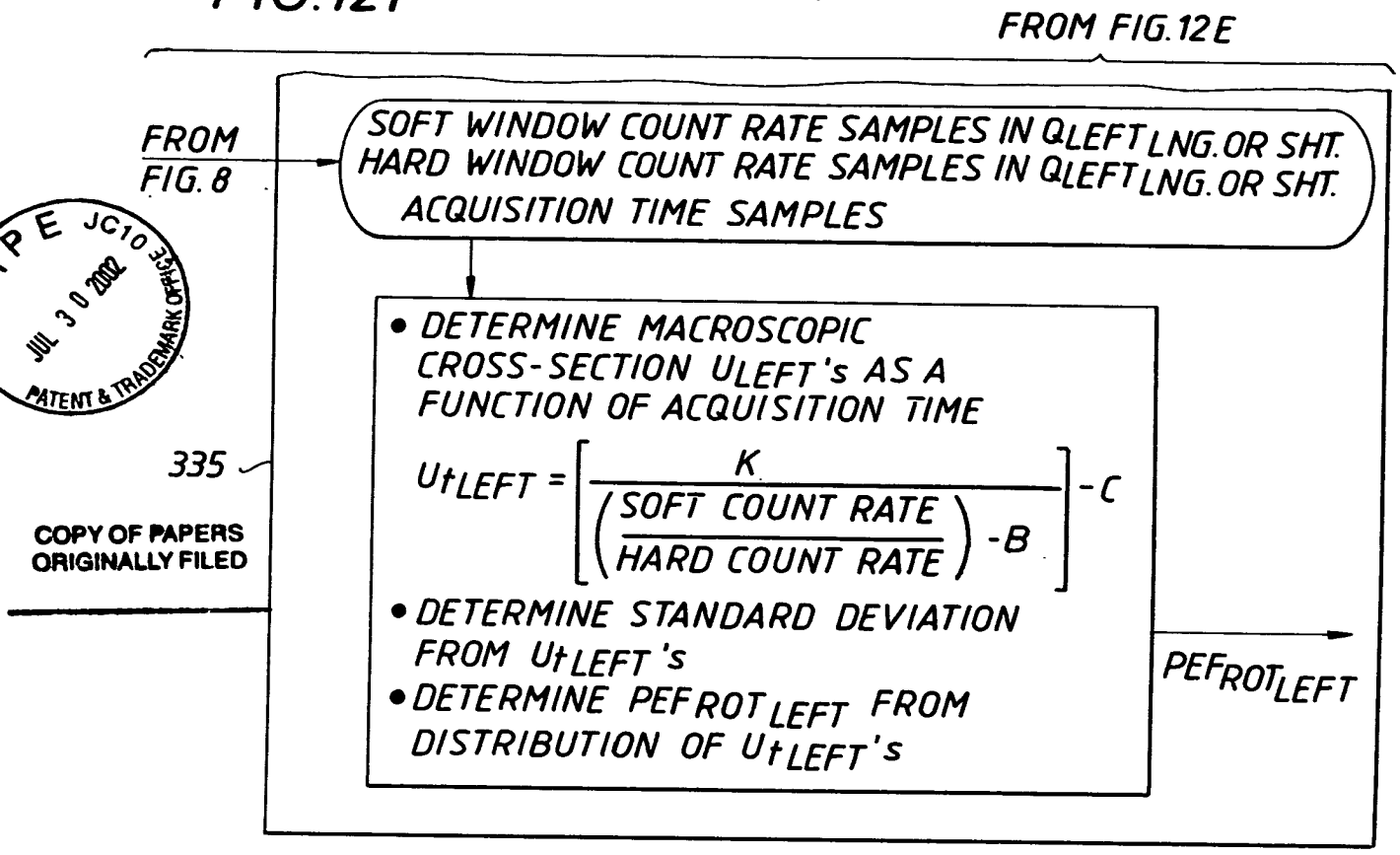


FIG. 13

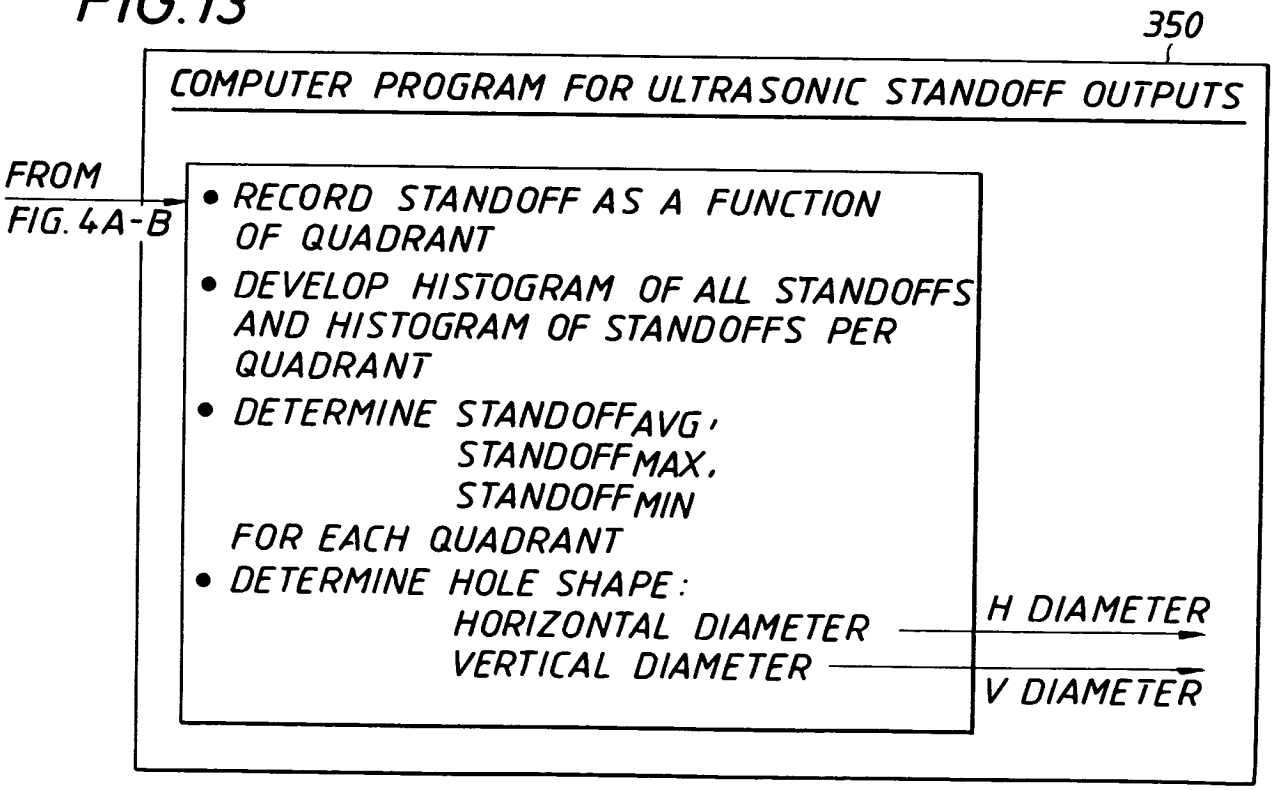


FIG. 14A

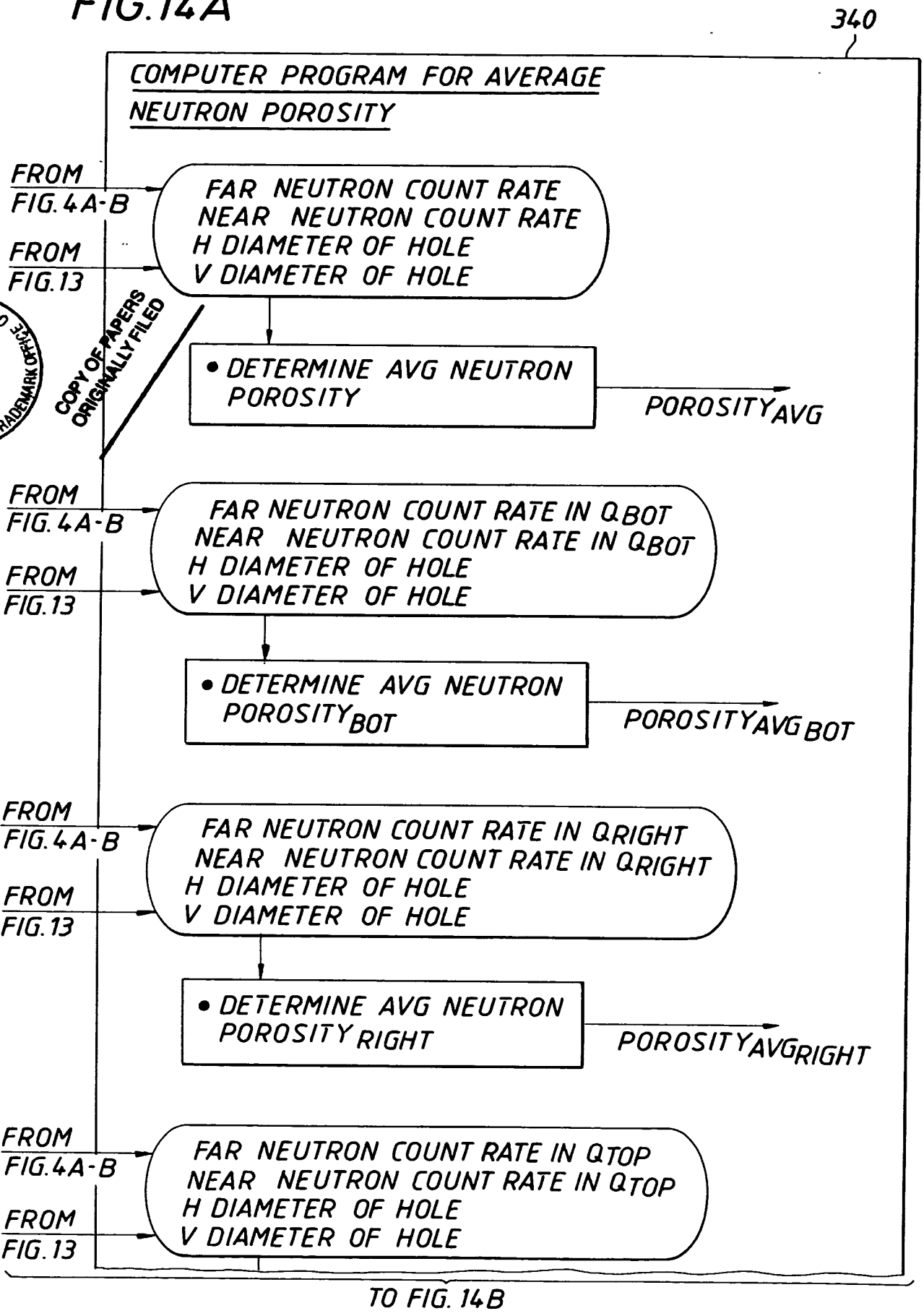


FIG. 14B

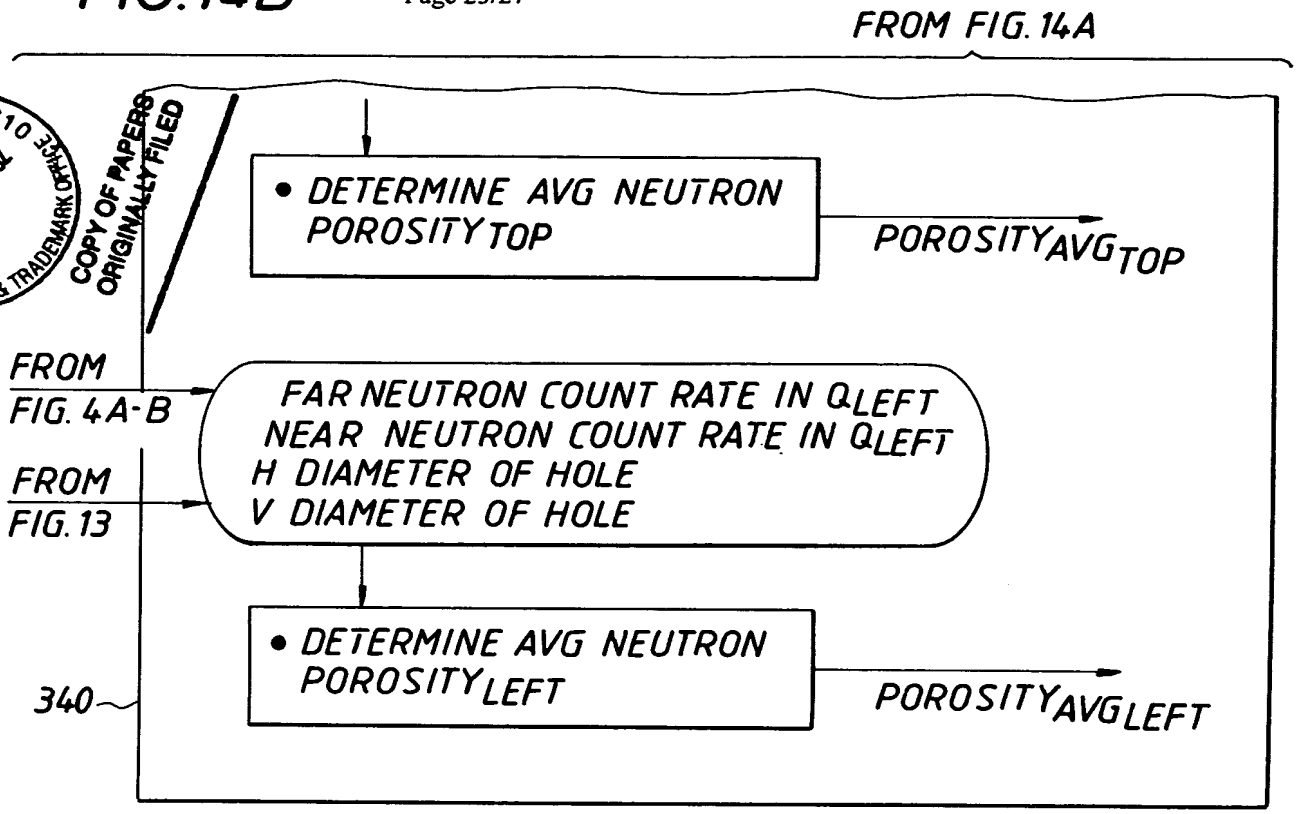


FIG. 15A

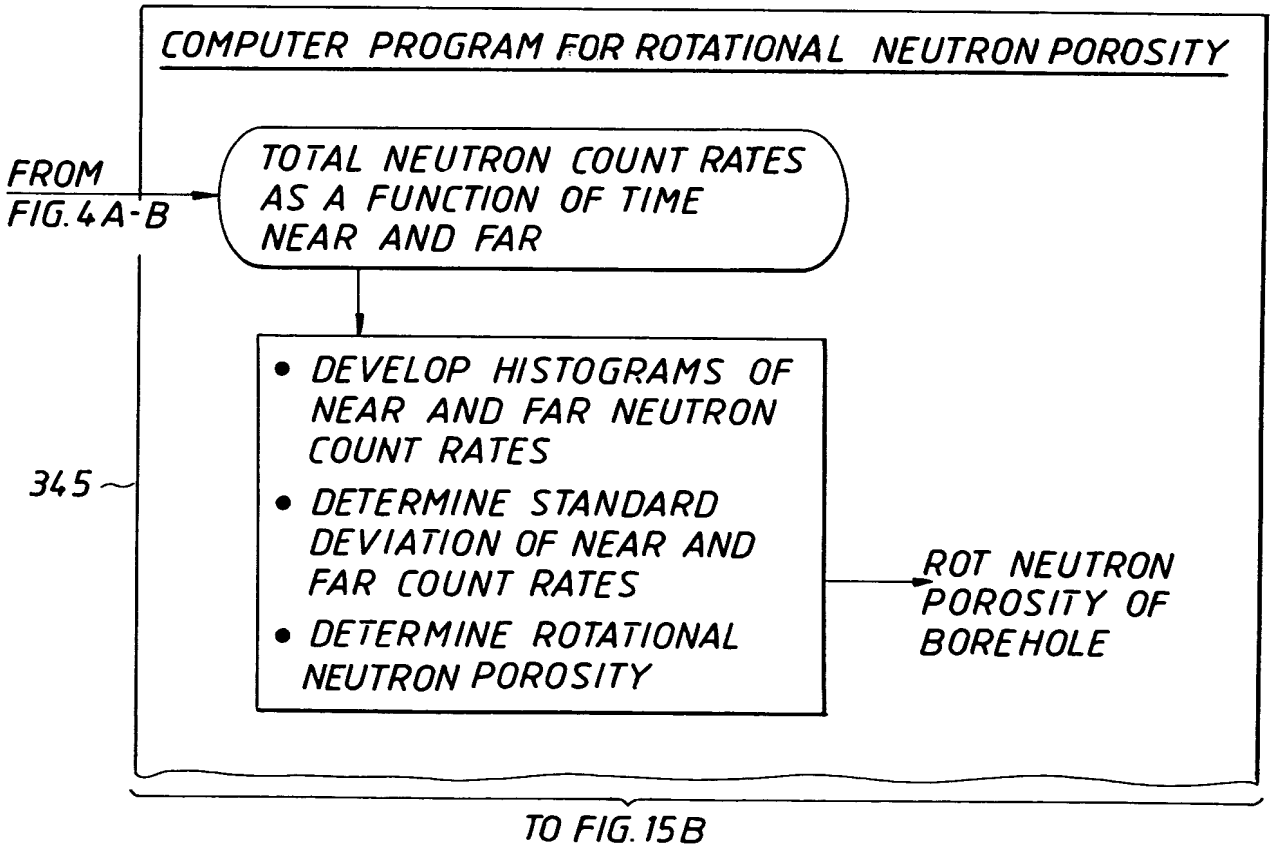


FIG. 15B

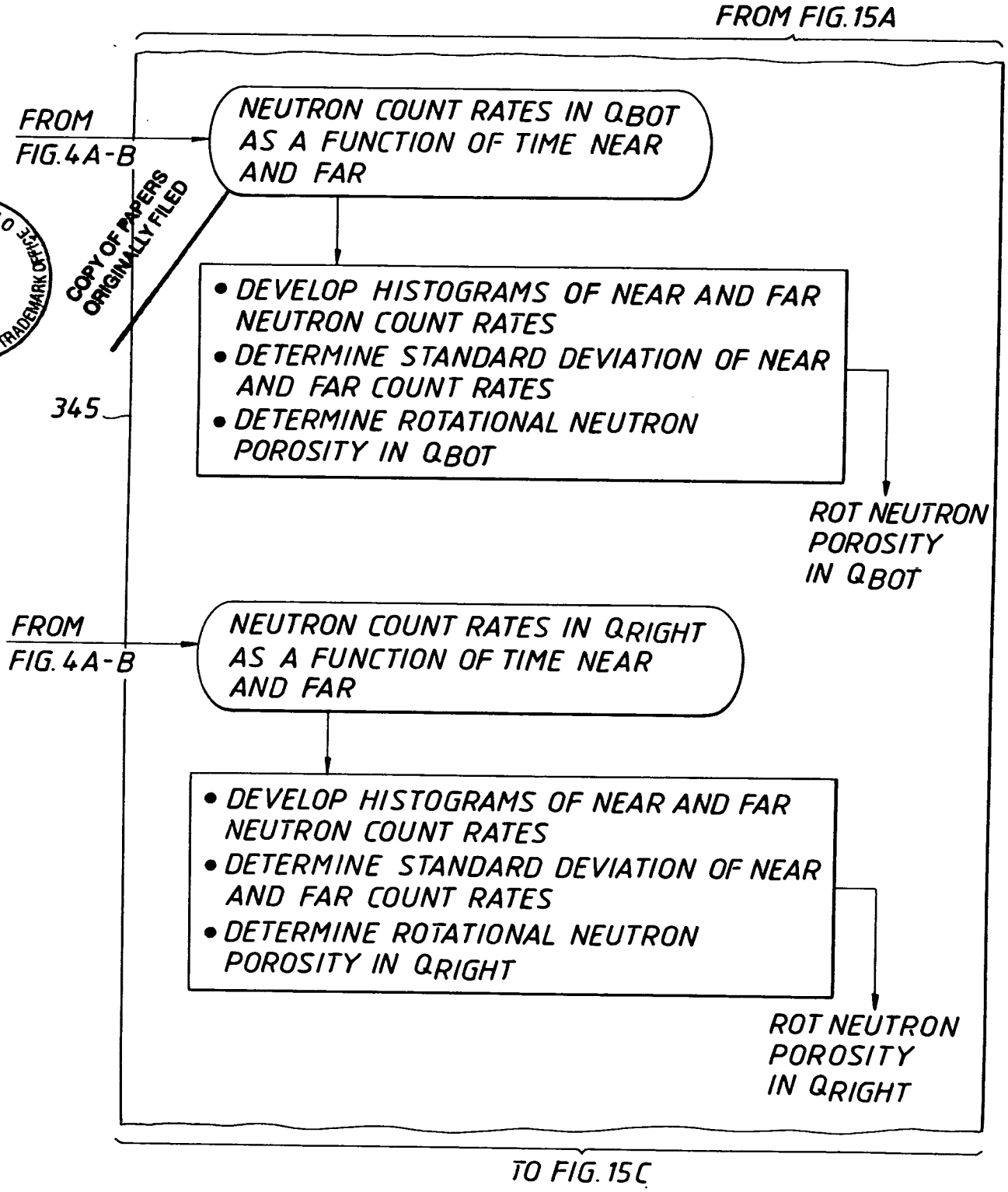
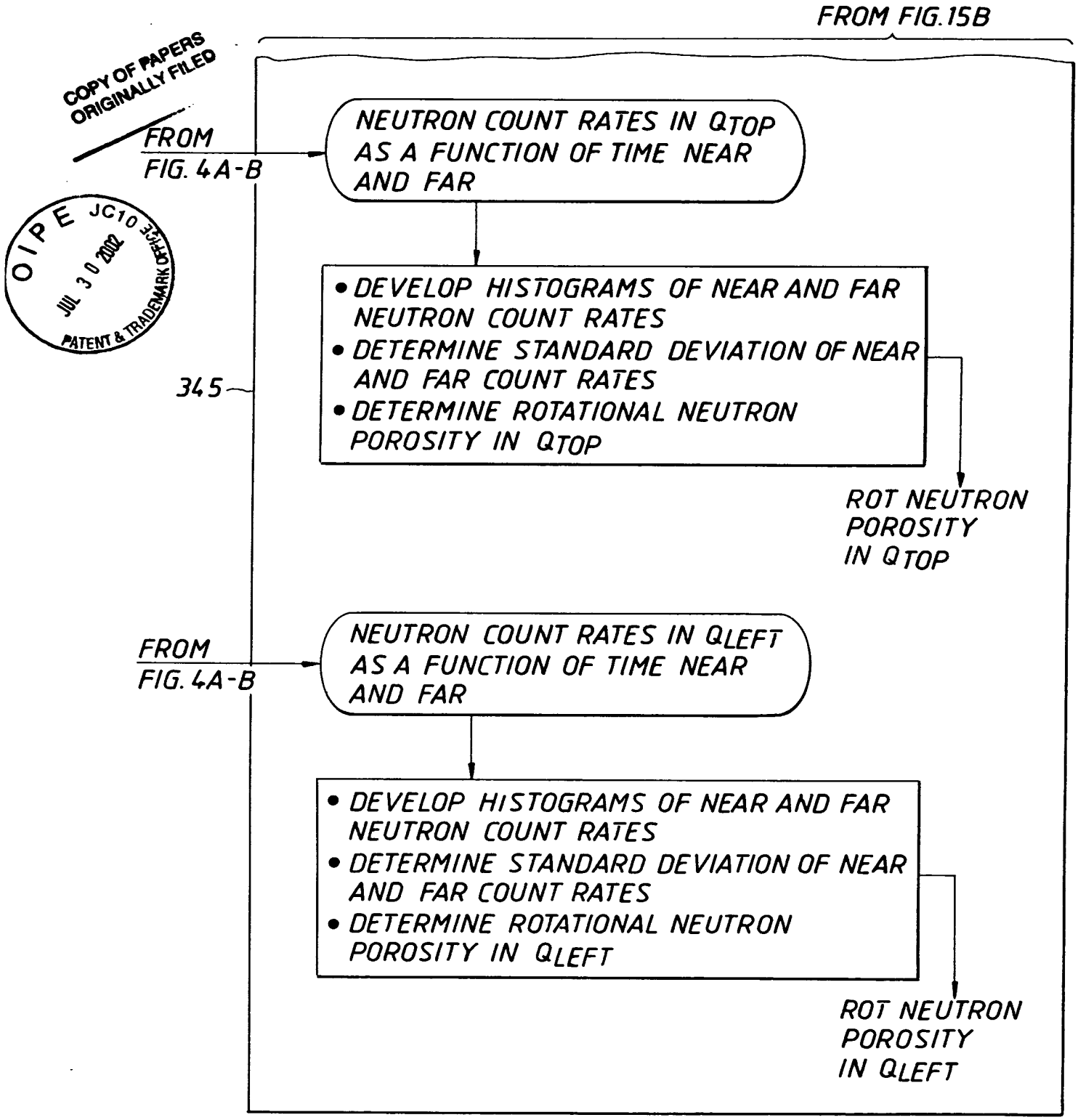


FIG. 15C



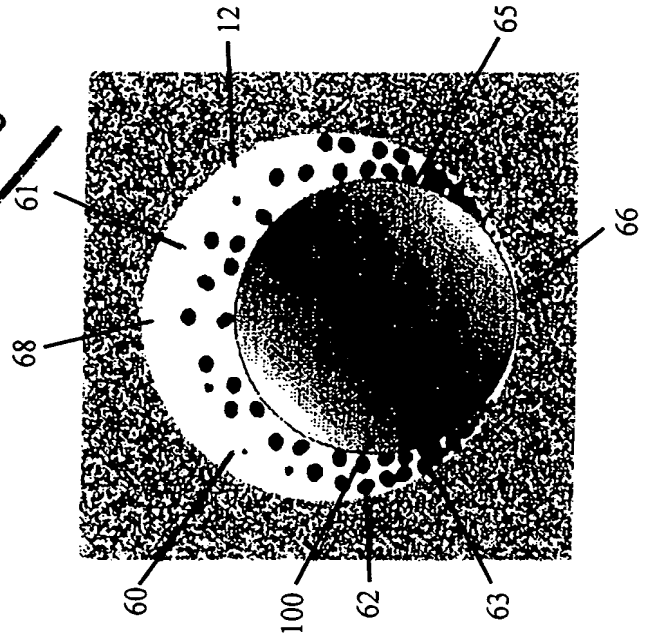


FIG. 16B

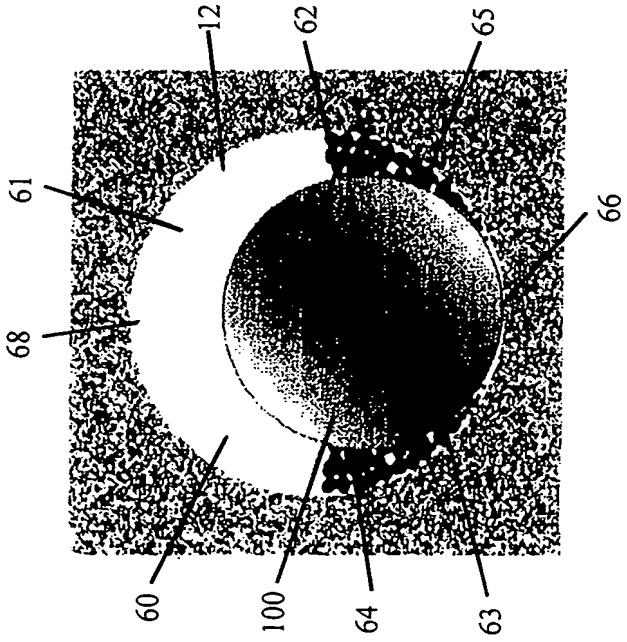


FIG. 16A

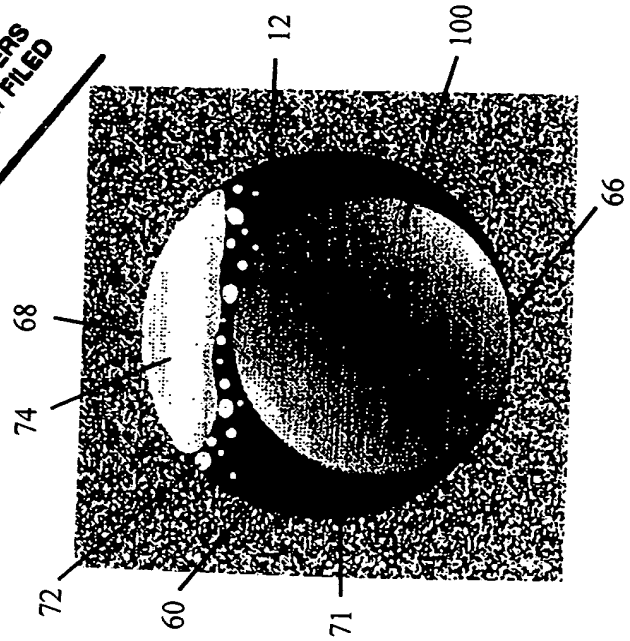


FIG. 17B

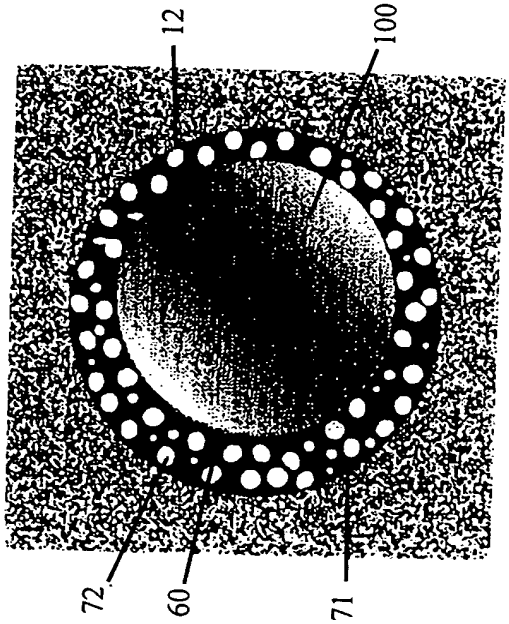


FIG. 17A